# NAVAL POSTGRADUATE SCHOOL

**MONTEREY, CALIFORNIA**

# THESIS

**TRANSITIONING THE TACTICAL MARINE CORPS TO IPv6**

by

Christopher M. Fodera

September 2011

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| REPORT DOCUMENTATION PAGE | | | *Form Approved OMB No. 0704–0188* |
|---|---|---|---|
| Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202–4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704–0188) Washington DC 20503. | | | |
| **1. AGENCY USE ONLY *(Leave blank)*** | **2. REPORT DATE** September 2011 | **3. REPORT TYPE AND DATES COVERED** Master's Thesis | |
| **4. TITLE AND SUBTITLE:** Transitioning the Tactical Marine Corps to IPv6 | | | **5. FUNDING NUMBERS** |
| **6. AUTHOR:** Christopher M. Fodera | | | |
| **7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)** Naval Postgraduate School Monterey, CA 93943–5000 | | | **8. PERFORMING ORGANIZATION REPORT NUMBER** |
| **9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES)** N/A | | | **10. SPONSORING/MONITORING AGENCY REPORT NUMBER** |
| **11. SUPPLEMENTARY NOTES** The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol Number: NA. | | | |
| **12a. DISTRIBUTION / AVAILABILITY STATEMENT** Approved for public release; distribution is unlimited | | | **12b. DISTRIBUTION CODE** |

**13. ABSTRACT (maximum 200 words)**


As communication in tactical arenas continues to trend from serial to Internet Protocol (IP) based, the necessity for tactical programs of record to embrace IP communications becomes more and more imperative. While many Marine Corps tactical communications programs of record already recognize this trend and its significance, some are affected more heavily than others.

Numerous advantages exist for transitioning from Internet Protocol version 4 to Internet Protocol version 6, and a top-down transition makes most sense for deployed and deploying units; the Data Distribution System-Modular is the system best suited to take on this role.

The Naval Postgraduate School's Center for Network Innovation and Experimentation (CENETIX) and Tactical Network Topology (TNT) field experimentation program, along with the Marine Corps Tactical Systems Support Activity (MCTSSA), can take on this task of transitioning the Tactical Marine Corps to IPv6; the commonality of the Defense Research Engineering Network (DREN) will allow for collaboration and testing that will greatly benefit our war fighters.


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|---|---|---|---|
| **14. SUBJECT TERMS**: IPv6, Transition, DDS-M, Tactical Networking | | | **15. NUMBER OF PAGES** 51 |
| | | | **16. PRICE CODE** |
| **17. SECURITY CLASSIFICATION OF REPORT** Unclassified | **18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified | **19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified | **20. LIMITATION OF ABSTRACT** UU |

NSN 7540–01–280–5500 Standard Form 298 (Rev. 8–98)
Prescribed by ANSI Std. Z39.18

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**TRANSITIONING THE TACTICAL MARINE CORPS TO IPv6**

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Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF SCIENCE IN INFORMATION TECHNOLOGY MANAGEMENT**

from the

**NAVAL POSTGRADUATE SCHOOL**
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# ABSTRACT

As communication in tactical arenas continues to trend from serial to Internet Protocol (IP) based, the necessity for tactical programs of record to embrace IP communications becomes more and more imperative. While many Marine Corps tactical communications programs of record already recognize this trend and its significance, some are affected more heavily than others.

Numerous advantages exist for transitioning from Internet Protocol version 4 to Internet Protocol version 6, and a top-down transition makes most sense for deployed and deploying units; the Data Distribution System-Modular is the system best suited to take on this role.

The Naval Postgraduate School's Center for Network Innovation and Experimentation (CENETIX) and Tactical Network Topology (TNT) field experimentation program, along with the Marine Corps Tactical Systems Support Activity (MCTSSA), can take on this task of transitioning the Tactical Marine Corps to IPv6; the commonality of the Defense Research Engineering Network (DREN) will allow for collaboration and testing that will greatly benefit our war fighters.

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| CENETIX | Center for Network Innovation and Experimentation |
| CUCM | Cisco Unified Communications Manager |
| DDS-M | Data Distribution System-Modular |
| DHCP | Dynamic Host Configuration Protocol |
| DICE | DoD Interoperability Communications Exercise |
| DISN | Defense Information System Network |
| DoD | Department of Defense |
| FTP | File Transfer Protocol |
| GIG | Global Information Grid |
| HTTP | HyperText Transfer Protocol |
| IP | Internet Protocol |
| IPv4 | Internet Protocol version 4 |
| IPv6 | Internet Protocol version 6 |
| JITC | Joint Interoperability Test Command |
| LAN | Local Area Network |
| MAGTF | Marine Air-Ground Task Forces |
| MARCORSYSCOM | Marine Corps Systems Command |
| MCSC | Marine Corps Systems Command |
| MCTSSA | Marine Corps Tactical Systems Support Activity |
| NPS | Naval Postgraduate School |
| OS | Operating System |
| POA&M | Plan Of Action and Milestones |

| | |
|---|---|
| RFC | Request for Comments |
| SBU | Sensitive-But-Unclassified |
| SIM/STIM | Simulation / Stimulation |
| SOCOM | Special Operations Command |
| SMTP | Simple Mail Transfer Protocol |
| SSH | Secure Shell |
| STIG | Security Technical Implementation Guides |
| STEP | Standardized Tactical Entry Point |
| SUT | System Under Test |
| SYSCOM | Systems Command (synonymous with MCSC) |
| TCP | Transmission Control Protocol |
| TDS | Tactical Data Systems |
| TDN | Tactical Data Networks |
| TNT | Tactical Network Topology |
| TS | Top Secret |
| TS/SCI | Top Secret / Sensitive-Compartmented-Information |
| UAV | Unmanned Aerial Vehicle |
| UDP | User Datagram Protocol |
| UE | Unclassified Encrypted |
| USMC | United States Marine Corps |
| VoIP | Voice over Internet Protocol |
| VTC | Video Teleconference |

# ACKNOWLEDGMENTS

To my wife, Andrea, thank you for your constant support and never-ending patience. Your love for our wonderful children and me is inspirational; being with you all is the most important thing in my life.

Dave Cabrera's constructive criticism and general wealth of knowledge made him an easy pick as a second reader. I learned to trust Dave implicitly while deployed and like always, he has never steered my wrong. Paul Nyenhuis has been invaluable in the vision and scope of this effort. I would also like to thank Doctor Alex Bordetsky for his vision on this thesis.

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# I. INTRODUCTION

## A. BACKGROUND

### 1. The DDS-M

The Tactical Data Networks (TDN) Project Officer at Marine Corps Systems Command (MCSC) identified the need for interoperability assessments on the Data Distribution System-Modular (DDS-M). The results of these assessments will determine the extent of joint interoperability for the DDS-M when transitioning from Internet Protocol version 4 (IPv4) to Internet Protocol version 6 (IPv6).

The DDS-M was previously tested for interoperability by Joint Interoperability Test Command (JITC), but IPv6 testing was not completed. Specific protocols tested include: HTTP, FTP, SMTP, VoIP, and VTC IPv6 requirements. Follow-on participation will allow additional IPv6 testing to continue and address previously identified shortfalls.

The Marine Corps deploys Marine Air-Ground Task Forces (MAGTFs) throughout the world to fulfill operational requirements, often in joint/combined operating environments. During these deployments, MAGTFs require access to strategic, theater, and tactical communications networks and information systems that support functional capabilities for command, control, communications, administration, logistics and intelligence. TDN DDS is the data communications backbone for the MAGTF augmenting and extending Defense Information System Network (DISN) services.

The DDS-M was developed to support the MAGTF command and control communications mission objectives. It was designed to provide Internet Protocol (IP) based data routing, information processing and storage, as well as network extension capabilities for deployed Marine Corps forces. The DDS-M features a flexible and modular Local Area Network (LAN) capability to provide services to the Marine Corps Tactical Data Systems (TDS) and other DDS-M systems. The

DDS-M can function as the file server supporting typical LAN services such as file sharing and electronic mail. A DDS-M suite also has the switching, processing, and storage capacity, along with the flexibility to support operations at a single security level.

A DDS-M suite can operate from the Sensitive-But-Unclassified (SBU) up to the Top Secret (TS)/Sensitive-Compartmented-Information (SCI) level and will contain an integral Inline Network Encryption (INE) device to support tunneling. Components of the DDS-M are integrated by functional groups into transit and storage cases for unit transport (Figure 1).

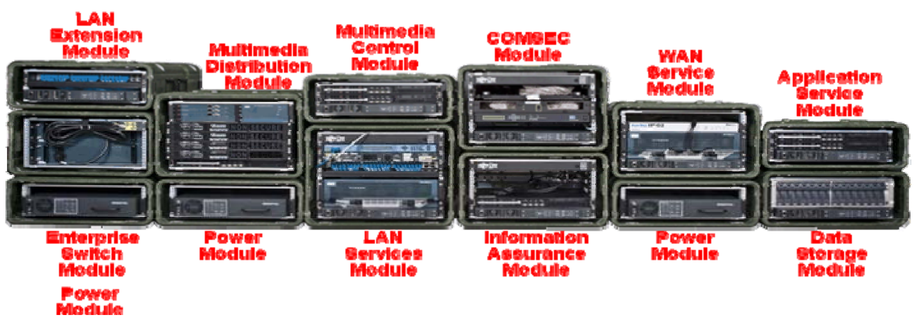



Figure 1. DDS-M

The LAN Extension Module (LSM), LAN Services Module and the Enterprise Switch Module (ESM) provide Layer 2/3 functionality to the DDS-M. The WAN Service Module provides Layer 3 functionality. The Media Distribution Module (MDM), Media Control Module (MCM), Application Service Module (ASM), and Data Storage Module (DSM) provide Layer 4 functionality to the DDS-M. The Power Modules and COMSEC Modules will not be addressed in this thesis as they are outside the scope of the study. The Information Assurance Module will not be addressed in this thesis, as it is not yet fielded by the Marine Corps.

## 2. The Protocols Compared

Table 1 outlines many of the differences between IPv4 and IPv6. There is a give and take that can be seen from an understanding of this transition.

| IPv4 | IPv6 |
|---|---|
| Source and destination addresses are 32 bits (4 bytes) in length. | Source and destination addresses are 128 bits (16 bytes) in length. |
| IPSec support is optional. | IPSec support is required. |
| No identification of packet flow for QoS handling by routers is present within the IPv4 header. | Packet flow identification for QoS handling by routers is included in the IPv6 header using the Flow Label field. |
| Fragmentation is done by both routers and the sending host. | Fragmentation is not done by routers, only by the sending host. |
| Header includes a checksum. | Header does not include a checksum. |
| Header includes options. | All optional data is moved to IPv6 extension headers. |
| Address Resolution Protocol (ARP) uses broadcast ARP Request frames to resolve an IPv4 address to a link layer address. | ARP Request frames are replaced with multicast Neighbor Solicitation messages. |
| Internet Group Management Protocol (IGMP) is used to manage local subnet group membership. | IGMP is replaced with Multicast Listener Discovery (MLD) messages. |
| ICMP Router Discovery is used to determine the IPv4 address of the best default gateway and is optional. | ICMP Router Discovery is replaced with ICMPv6 Router Solicitation and Router Advertisement messages and is required. |
| Broadcast addresses are used to send traffic to all nodes on a subnet. | There are no IPv6 broadcast addresses. Instead, a link-local scope all-nodes multicast address is used. |
| Must be configured either manually or through DHCP. | Does not require manual configuration or DHCP. |
| Uses host address (A) resource records in the Domain Name System (DNS) to map host names to IPv4 addresses. | Uses host address (AAAA) resource records in the Domain Name System (DNS) to map host names to IPv6 addresses. |
| Uses pointer (PTR) resource records in the IN-ADDR.ARPA DNS domain to map IPv4 addresses to host names. | Uses pointer (PTR) resource records in the IP6.ARPA DNS domain to map IPv6 addresses to host names. |
| Must support a 576-byte packet size (possibly fragmented). | Must support a 1280-byte packet size (without fragmentation). |

Table 1. Comparison of IPv4 and IPv6[1]

[1] "Transition Planning for Internet Protocol version 6 (IPv6)," accessed July 5, 2010, http://www.whitehouse.gov/omb/memoranda/fy2005/m05–22.pdf.

While the comparison mainly paints a picture that IPv6 is an improvement from IPv4 in all ways, it does not take into account how the change in header structure and size (IPv4 being 20 octets and IPv6 being 40 octets) may impact network performance on tactical communications links where bandwidth is generally limited.

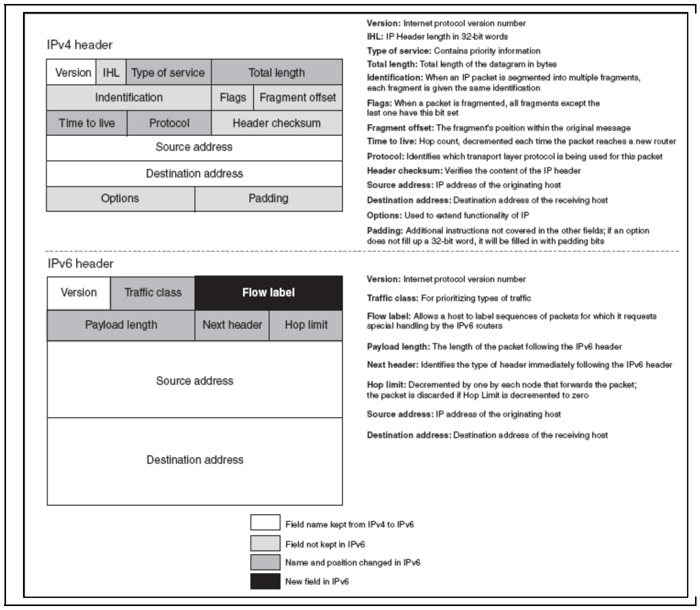



Figure 2. IPv4 and IPv6 Headers Compared[2]

## B. PURPOSE OF STUDY

The purpose of this thesis is to design and develop a test plan and architecture that will assess the IPv6 functionality, conformance, performance, security, and interoperability of the DDS-M. The result will be a thorough and appropriate test plan to determine whether the system meets the following requirements as defined by JITC:

a) an IPv6 Capable Product

b) Joint Interoperability Certification

[2] "Transition Planning for Internet Protocol version 6 (IPv6)," accessed July 5, 2010, http://www.whitehouse.gov/omb/memoranda/fy2005/m05–22.pdf.

## C. TEST OBJECTIVES

The objectives of the test will be to verify/demonstrate the interoperability of DDS-M in a Joint Environment when transitioned from IPv4 to IPv6 in the following areas:

1. IPv6 functionality
2. IPv6 conformance
3. IPv6 performance
4. IPv6 security

## D. TEST SCOPE

The testing will encompass various aspects of the system and components. The system is comprised of multiple components that fall into different IPv6 Product Classes, as defined in the DoD IPv6 Standard Profiles for IPv6 Capable Products version 6.0. Each of these product classes have unique mandatory and optional requirements and will be evaluated separately. The test will be an iterative process to accurately evaluate both the individual components and the system in its entirety.

The test is divided into four phases. The focus of Phase 1 is to assess functionality and performance of IPv6 applications, services, transport and routing. This phase will test three network scenarios; IPv4, dual-stack, and IPv6 native. The focus of Phase 2 is to assess conformance of individual system components. Phase 3 will assess security aspects of IPv6 products. Phase 4 is interoperability testing; during this phase, information exchanges for voice, video, and data will be assessed in unclassified and unclassified encrypted networks.

## E. TEST CONSTRAINTS

The test will be conducted on a closed network between MCTSSA and JITC; thus, there will be no connection to the Internet or any other networks. MCTSSA must rely on JITC's ability to emulate the required network and services expected for IPv6 testing.  Specific tests that cannot be supported will be executed in the IPv6 lab at MCTSSA.  Areas untested will be deferred to later events.

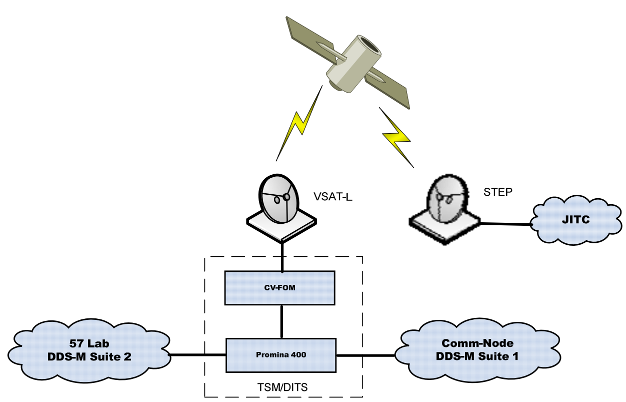
# II. TEST ENVIRONMENT

## A. TEST LOCATION

The IPv6 test will take place at MCTSSA aboard Camp Pendleton, California, with Defense Research Engineering Network (DREN) or Satellite connectivity to JITC’s simulated Standardized Tactical Entry Point (STEP) at Fort Huachuca, Arizona. Aboard MCTSSA, the systems under test will be located in Bldg-31357 lab and in the Communications (Comm) Node shelter, located on the south side of Bldg-31357. Transmission systems will be located in the lot north of Bldg-313059.

## B. TEST CONFIGURATION

The IPv6 test will be conducted as part of Department of Defense (DoD) Interoperability Communications Exercise (DICE) and participating systems will be connected as illustrated in Figure 3. This diagram depicts the high-level architecture to support the test. All equipment, systems, shelters, and facilities will be interconnected using standard commercial and tactical interface cabling and transmission systems as required.




| LEGEND: | | | |
|---|---|---|---|
| DDS-M | Data Distribution System - Modular | STEP | Standardized Tactical Entry Point |
| VSAT-L | Very Small Aperture Terminal - Large | JITC | Joint Interoperability Test Command |
| TSM/DITS | Transition Switch Module/ Deployable Integrated Transport Suite | CV-FOM | ConVerter – Fiber Optics Modem |

Figure 3. High Level Test Diagram

The two suites (1 and 2) depicted in Figure 3 will be configured uniquely to support the different scenarios and phases of testing in order to reduce the amount of reconfiguration required during transition between scenarios. Table 2 lists the individual suites, associated phases, and description of the test. Suite 1 will be configured as the legacy suite while Suite 2 will have newer Operating Systems (OS) and application software installed for evaluation.

| Suite | Phase | Description |
|---|---|---|
| 1&2 | Phase 1 - Functionality | IPv4 baseline system performance |
| 1&2 | Phase 1 - Functionality | Dual-Stack system performance |
| 2 | Phase 1 - Functionality | IPv6 native system performance |
| 1&2 | Phase 2 - Conformance | IPv6 conformance |
| TBD | Phase 3 - Security | IPv6 security |
| 2 | Phase 4 - Interoperability | Interoperability of enhanced suite |

Table 2. Phases and Objectives

## C. PARTICIPATING SYSTEMS

The systems participating in the IPv6 test are divided into two groups. The first group is the SUT which includes two systems. The second group consists of Other Participating Systems, simulation/stimulation (sim/stim) tools, and data collection systems that support information and data transfer throughout the test architecture. Table 3 lists the hardware and software for the IPv6 test.

| System Hardware/Software | | | | |
|---|---|---|---|---|
| **Qty** | **System** | **Hardware** | **Software Version** | **Location** |
| **System Under Test** | | | | |
| 2 | DDS-M | Various | Various | Bldg 57 lab / Comm Node |
| **Other Participating Systems** | | | | |
| 1 | VSAT | VSAT-L | N/A | N Bldg 313059 |
| 1 | DREN | N/A | N/A | Bldg 57 lab |
| **Simulation/Stimulation** | | | | |
| 1 | Spirent | Test Center / Avalanche | 3.7 | Bldg 57 lab |
| 1 | Ixia | IxNetwork / IxLoad / IxChariot / IxAnvil | 6.0 | Bldg 57 lab |
| 1 | Breaking Point | Storm / Application Threat Intelligence | 2.2 | Bldg 57 lab |
| **Data Collection/Analysis** | | | | |
| 3 | NetScout | 2U Server | Linux | Bldg 57 lab |
| 5 | Wireshark | Laptop | 1.6.2 | Bldg 57 lab |
| 5 | Riverbed Cascade Pilot | Laptop | MS Win7 | Bldg 57 lab |

Table 3. System Hardware/Software and Location

All hardware, software, and firmware versions for the SUT and other participating systems will be recorded and documented in the test report. Documentation of the appropriate versions will occur during the data collection period of each phase.

### 1. System Under Test

The DDS-M system enables deployed Marines to establish secure, networked voice, data, video conferencing and other communication capabilities among commanders, joint and coalition forces. Based on commercial-off-the-shelf equipment, the DDS-M comprises routers, switches, computers, power supply and other equipment needed to access the Defense Information System

Network (DISN), Secret Internet Protocol Router Network (SIPRNet) and Non-secure Internet Protocol Router Network (NIPRNet), as well as coalition and joint-forces networks.[3]

### 2. Other Participating Systems

#### *a. VSAT-L*

The purpose of the SWAN-D/VSAT is to enable USMC intra-theater communications; to allow forward deployed elements to "break" the terrestrial line-of-sight tether and extend their operations farther from their higher echelon command or to enable operations in terrain not conducive to Line-of-sight (LOS) operations.[4]

#### *b. DREN*

The Defense Research and Engineering Network (DREN) is DoD's recognized research and engineering network. The DREN is a robust, high-capacity, low-latency nation-wide network that provides connectivity between and among the HPCMP's geographically dispersed High Performance Computing (HPC) user sites, HPC Centers, and other networks. The DREN provides digital, imaging, video, and audio data transfer services between defined service delivery points (SDPs). SDPs are specified in terms of WAN bandwidth access, supported network protocols [Multi Protocol Label Switching, Internet Protocol (IP), Asynchronous Transfer Mode (ATM)], and local connection interfaces.

[3] "General Dynamics Awarded $130 Million Contract to Produce Tactical Data Network Systems for the U.S. Marine Corps," accessed Aug 6, 2011, http://www.gdc4s.com/news/detail.cfm?prid=285.

[4] "2010 SWAN Fact Sheet," accessed Aug 6, 2011, http://www.marcorsyscom.usmc.mil/sites/cins/Fact%20Books/NSC/SATCOM/2010%20SWAN%20Fact%20Sheet.pdf.

DREN currently supports both IP version 4 (IPv4) and IP version 6 (IPv6) at bandwidths from DS-3 (45 Mbps) at user sites up to OC-48c (2.488Gbps) at selected HPC Centers.[5]

### 3. Simulation/Stimulation Tools

#### *a. Spirent*

Spirent's Test Center is an application of high scale, realistic traffic ensures that networks and components are evaluated accurately and proven to perform as services scale.[6] Avalanche is a line rate, 1 Gbps and 10Gbps Layer 4–7 multi-protocol stateful traffic performance solution that is capable multi 10Gbps of stateful application traffic generation.[7]

#### *b. Ixia*

IxNetwork is designed to test network infrastructure, capacity, scalability, and convergence providing rapid isolation of network issues, service modeling at Internet scale, carrier class scaling, and accurate convergence measurement.[8]

IxLoad is a scalable solution for testing converged multiplay services, application delivery platforms, and security devices and systems. IxLoad emulates data, voice, and video subscribers and associated protocols to ensure quality of experience (QoE). IxLoad also applies malware and distributed denial of service (DDoS) attacks for security effectiveness and accuracy testing.[9]

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[5] "Defense Research and Engineering Network Definition," accessed Aug 6, 2011, http://www.hpcmo.hpc.mil/Htdocs/DREN/dren-def.html.

[6] "Spirent Test Center," accessed Aug 6, 2011, http://www.spirent.com/Solutions-Directory/Spirent-TestCenter.aspx.

[7] "Avalanche," accessed Aug 6, 2011, http://www.spirent.com/Solutions-Directory/Avalanche.aspx.

[8] "IxNetwork for Network Topology Testing and Traffic Analysis," accessed Aug 6, 2011, http://www.ixiacom.com/products/ixnetwork/index.php.

[9] "IxLoad: Overview," accessed Aug 6, 2011, http://www.ixiacom.com/products/ixload/index.php.

IxChariot is Ixia's network assessment tool for troubleshooting networks and applications; it allows for simulation of real-world applications to predict device and system performance under realistic load conditions.[10] IxANVL (Automated Network Validation Library) is Ixia's solution for automated network/protocol validation.[11]

### *c. BreakingPoint*

The BreakingPoint Storm produces high-performance traffic from hundreds of real-world applications, load from millions of users, and comprehensive security coverage that includes thousands of current attacks and malware, as well as obfuscation and evasion techniques. The product features built-in automation to:

- Produce a standardized Resiliency Score™ to measure network and data center performance, security, and stability
- Measure the performance of massive virtualized infrastructures in the face of peak user load and attack
- Validate the accuracy and performance of Lawful Intercept and Data Loss Prevention systems[12]

The BreakingPoint Application and Threat Intelligence (ATI) program provides comprehensive application protocols and attacks, as well as feature updates and responsive service and support with access to the very latest cybersecurity updates.[13]

[10] " IxChariot," accessed Aug 6, 2011, http://www.ixchariot.com/products/datasheets/ixchariot.html.

[11] "IxANVL - Automated Network Validation Library," accessed Aug 6, 2011, http://www.ixiacom.com/products/ixanvl/index.php.

[12] "BreakingPoint Storm," accessed Aug 6, 2011, http://www.breakingpointsystems.com/cyber-tomography-products/breakingpoint-storm-ctm/.

[13] "BreakingPoint Application and Threat Intelligence," accessed Aug 6, 2011, http://www.breakingpointsystems.com/cyber-tomography-products/breakingpoint-service-and-support/.

### 4. Data Collection/Analysis Tools

#### *a. NetScout*

Stored packet data is directly accessed with unrestricted mining without requiring an external server. The InfiniStream Console provides a streamlined view to vital data for troubleshooting high-priority issues.[14]

Providing granular visibility into the most complex and demanding network environments, nGenius Performance Manager leverages robust and pervasive packet flow data collected by a comprehensive family of nGenius intelligent data sources. Deployed across the network, nGenius intelligent data sources capture and analyze real-time IP traffic flows. nGenius Performance Manager also leverages NetFlow and sFlow data from deployed network devices to provide broader insight at key network aggregation points.[15]

#### *b. WireShark*

Wireshark is the world's foremost network protocol analyzer. It lets you capture and interactively browse the traffic running on a computer network. It is the de facto (and often de jure) standard across many industries and educational institutions.[16]

#### *c. Riverbed Cascade Pilot*

Cascade Pilot is a powerful packet analysis console that seamlessly integrates with Wireshark, Cascade Shark and Riverbed Steelhead for a fully distributed, easy to manage packet capture solution for assistance in

[14] "InfiniStream Consol," accessed Aug 6, 2011, http://www.netscout.com/products/service_provider/nSAS/sniffer_analysis/Pages/InfiniStream_Console.aspx.

[15] "nGenius Performance Manager," accessed Aug 6, 2011, http://www.netscout.com/products/enterprise/nSAS/ngenius_analysis/Pages/nGenius_Performance_Manager.aspx.

[16] "About Wireshark," accessed Aug 6, 2011, http://www.wireshark.org/about.html.

network troubleshooting. Fully integrated with Wireshark, Cascade Pilot uses an intuitive graphical user interface that maximizes user productivity by rapidly isolating the specific packets needed to diagnose and troubleshoot complex performance issues.[17]

## D. PHYSICAL TEST ENVIRONMENT LAYOUT

Figure 4 depicts the test lab locations and layouts for the IPv6 test environment. The IPv6 test will be conducted inside the lab within building 31357 and inside an enclosed shelter on the south side of building 31357 at MCTSSA. External connectivity to JITC (Ft. Huachuca) will be established via the VSAT-L, located in the lot north of building 313059.

[17] “Cascade Pilot Software,” accessed Aug 6, 2011, http://www.riverbed.com/us/products/cascade/cascade _pilot.php.

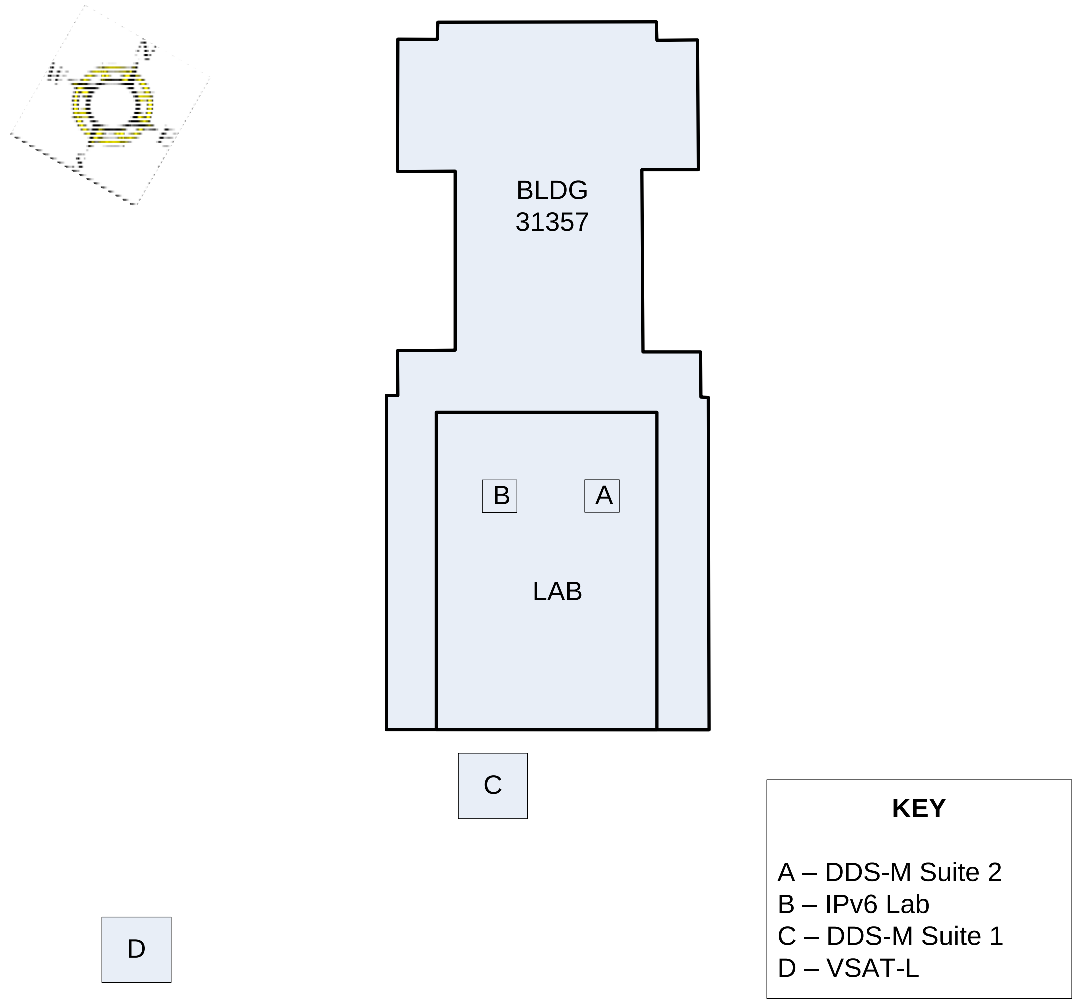


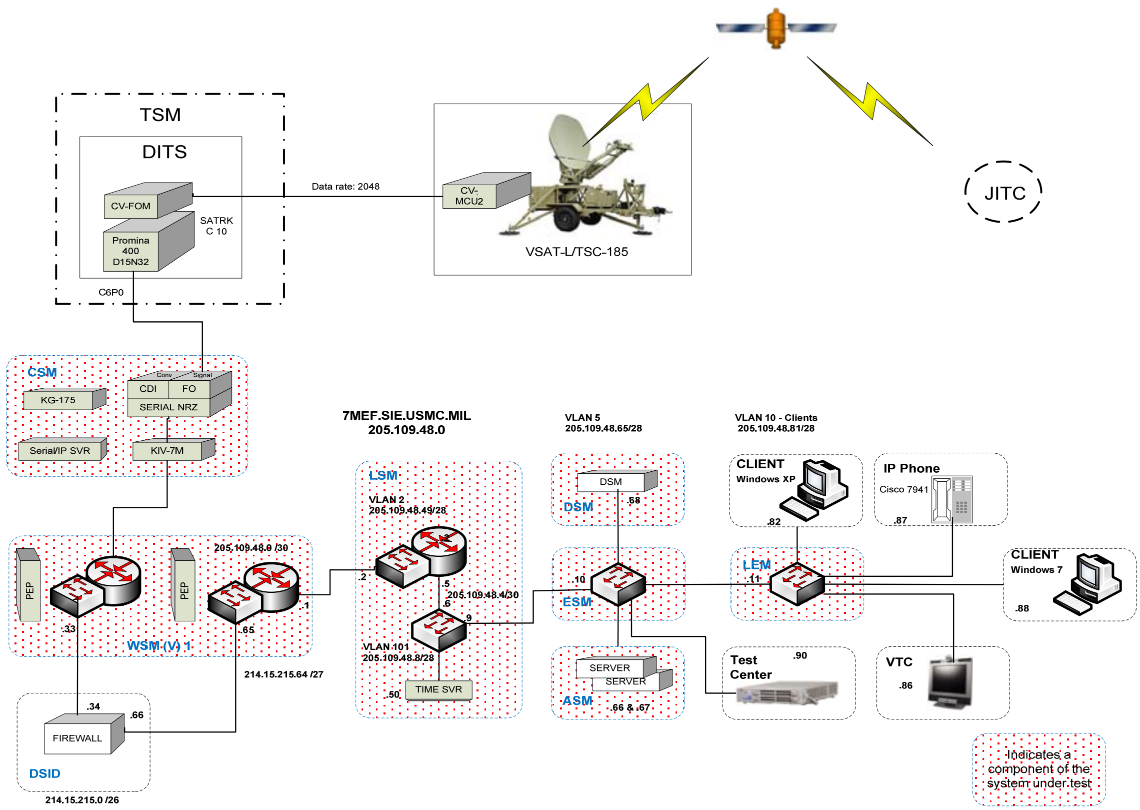

Figure 4. Physical Test Environment Layout

## E. SECURITY

IA scans of the systems under test will be conducted before testing begins. The IA process will confirm the system test configurations are consistent with the local approval authority's IA policies and DoD Security Technical Information Guide (STIG) for connecting. When connecting to JITC, the results will be uploaded to the DICE portal. The JITC Designated Approving Authority is responsible for ensuring the system follows DoD-required IA policies.

## F. DETAILED TEST ARCHITECTURE

Figure 5 represents the proposed network architecture that will be used during the test. Detailed equipment configurations for the systems involved will be provided in a final test report.




| LEGEND: | | | |
|---|---|---|---|
| ASM | Application Service Module | JITC | Joint Interoperability Test Command |
| CDI | Conditioned Di-phase Interface | LEM | Local Area Network Extension Module |
| CSM | Communications Security Module | LSM | Local Area Network Services Module |
| DITS | Deployable Integrated Transport Suite | NRZ | Non-Return-to-Zero |
| DSID | Deployed Security Interdiction Device | PEP | Performance Enhancing Proxy |
| DSM | Data Storage Module | TSM | Transition Switch Module |
| ESM | Enterprise Switch Module | VTC | Video Teleconferencing |
| FO | Fiber Optic | WSM | Wide Area Network Services Module |

Figure 5. Network Diagram

# III. TEST DESIGN

## A. OVERALL TEST APPROACH

The system will be tested using a logical and systematic evaluation sequence. This approach allows flexibility during testing and attempts to provide a complete picture of the current IPv6 status of the system. The goal of this test is to assess and report the present level of functionality (from the user perspective), the degree of conformance to the standards, comparative performance measurements, security posture, and interoperability with Joint and USMC Programs of Record. It is expected that the system will require multiple iterations of testing in order to meet full compliance. However, since this approach is designed to be sequential, follow-on tests of individual system components may not require full regression testing.

The testing approach begins by confirming the individual system components and network devices provide IPv6 functionality. This functionality is divided into two categories, limited and basic. For the purposes of this document, the following definitions are provided:

a. <u>Limited functionality</u>: the component or network device is capable of assigning an IPv6 address to the Network Interface Card (NIC), can successfully connect to the network, and can communicate (both dual-stack and IPv6 native) with other devices on the network.

b. <u>Basic functionality</u>: the application or service is able to function and communicate (both dual-stack and IPv6 native) with other devices on the network. During the functionality testing, the associated ports and protocols used to communicate will be identified and recorded.

The second area of testing is conformance. Conformance testing will be conducted on individual system components as stand-alone devices. Since system components will fall into multiple product classes, they must be evaluated separately, but could be grouped together for testing. The system components will be tested against the appropriate product class requirements defined in the DoD IPv6 Standard Profiles for IPv6 Capable Products Version 6.0.

The third area of testing is performance. Performance testing will be conducted on servers and network devices. The results will provide a basis for comparison between the network implementations (IPv4, dual-stack, and IPv6). Examples of the performance metrics to be recorded and analyzed include: application response time, transactions per second, packet loss, latency, jitter, and throughput. These metrics will be maintained for future analysis or comparison during subsequent testing.

The fourth area of testing is security. Host system, server, switch and router security testing is included in the conformance testing, since the IPv6 security feature requirements are currently defined for each of the product classes. Information Assurance (IA) devices have unique requirements defined and will not be included at this time.

The final area of testing is interoperability. Interoperability testing includes both internal (MAGTF) and external (Joint). Functional testing of the application(s), service(s), transport, and routing provides the basis for internal interoperability. Joint interoperability will expand the functional testing by evaluating interfaces with joint applications, services, transport, and routing.

For this test, one suite will be configured as a legacy (fielded) system and the second will be configured as an enhanced suite. Examples of the differences on the enhanced suite include, but are not limited to: servers running Windows Server 2008 and Exchange 2010 installations and routers/switches upgraded to newer Cisco Internetwork Operating System (IOS).

## B. PLANNED TESTS

The test will be conducted in phases as described in the following paragraphs. Phase 1 will focus on functionality, performance and interoperability. During this phase of testing, interoperability of voice, video, and data transmissions between end devices will be evaluated. Functionality and interoperability testing will include client-to-server, server-to-server, and SIM/STIM communications as listed in Table 4. Phase 2 will be conformance testing of individual system components. Phase 3 will be detailed/scheduled at a later time to assess the security devices within the system. Phase 4 will focus on joint interoperability. This phase can be combined as part of Phase 1 or scheduled as a separate phase, to support JITC testing.

| **Source** | **Destination** | **Service** |
|---|---|---|
| Workstation 1 (local) | Workstation 2 (remote) | VTC, Ping, Trace-route, Email |
| Workstation 2 (remote) | Workstation 1 (local) | VTC, Ping, Trace-route, Email |
| Workstation 1 (local) | Server 2 (remote) | HTTP, HTTPS, SSH, FTP, FTPS |
| Workstation 2 (remote) | Server 1 (local) | HTTP, HTTPS, SSH, FTP, FTPS |
| Server 1 (local) | Server 2 (remote) | Mail, VoIP |
| Server 2 (remote) | Server 1 (local) | Mail, VoIP |
| SIM/STIM 1 (local) | SIM/STIM 2 (remote) | RFC 2544, Network Loading & Layer 4–7 |
| SIM/STIM 2 (remote) | SIM/STIM 1 (local) | RFC 2544, Network Loading & Layer 4–7 |

Table 4. Source, Destination, and Service

### 1. Phase 1: Performance

Phase 1 testing will be divided into three different network scenarios (IPv4, dual-stack, and IPv6 native). For each scenario, the complete set of test procedures will be executed on both suites of equipment. Table 5 depicts the Cisco Internetwork Operating Systems (IOSes) on the 3845 Routers and 3750G Switches as well as the Operating Systems (OSes) on the servers. Suite 1 is configured as is currently fielded to Marines using the system in tactical environments. Known issues exist with the IOS version and OSes; they are not IPv6 capable. Suite 2 is configured as the engineers at MCTSSA and SYSCOM have deemed to be the best-case scenario for deployment of the DDS-M.

| Network Scenario | **SUITE 1** | **SUITE 2** |
|---|---|---|
| Scenario 1: IPv4<br>Scenario 2: Dual Stack<br>Scenario 3: IPv6 Native | Router: *12.4(15)T13, w/ AdvEntServices*<br>Switch: *12.2(50)SE4, w/ IP Services*<br>Servers: *Windows Server 2003*<br>Exchange: *Microsoft Exchange 2003* | Router: *12.4(15)T14, w/ AdvEntServices*<br>Switch: *12.4(50)SE4, w/ IP Services*<br>Servers: *Windows Server 2008*<br>Exchange: *Microsoft Exchange 2010* |

Table 5. Configuration Differences Between Suites

The Modules mainly affected by the above table are the LAN Extension Module (LEM), Enterprise Switch Module (ESM) and the LAN Services Module (LSM) for the Switch IOSes. The WAN Services Module (WSM) is the only module affected by the Router IOSes. The Application Service Module (ASM) and the Data Storage Module (DSM) are the Modules mainly affected by the Operating Systems (Microsoft Server and Microsoft Exchange).

Table 6 is a test matrix which highlights (via shading) the types of tests applicable to each of the product classes. The shaded cells grouped together identify when the metric is a result (or summary) of both client and server action(s). The table is further broken down to depict both user and performance metrics. The user metrics will be used for the overall pass/fail criteria, while the performance metrics will be used for the comparative analysis between the scenarios.

#### *a. Scenario 1*

The legacy suite (Suite 1) and enhanced suite (Suite 2) will be configured for an IPv4 based network. User and performance metrics will be captured and recorded. The performance metrics will become the baseline values for comparison.

#### *b. Scenario 2*

The systems and network devices will be re-configured for dual-stack operations (IPv4 and IPv6 protocols enabled). The user and performance metrics will be captured, recorded, analyzed and compared against the baseline results for Scenario 1.

#### *c. Scenario 3*

The systems and network devices will be re-configured for IPv6 native operations (IPv6 enabled and IPv4 disabled). The user and performance metrics will be captured, recorded, analyzed and compared against the results for Scenarios 1 and 2.

| Highlighted cells identify what applies to each sub-category of the objectives. This applies to the system and individual components. | | | | User Metrics | | | | | Performance Metrics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | IPv6 Functionality | | Application | | | Application | | | | Network | | | | | |
| Objective | Application or Category Client/Server | Protocol (Dest. Port) | Transport (Protocol #) | Limited Functions (IP Addressing) | Basic Functions (Application support) | Message Completion Threshold>=90%, Objective>=90% | Data Integrity Threshold>=99.9% Objective>=99.9% | Call Completion rate | Application Response Time | Transactions per Second | Voice Quality Mean Opinion Score (MOS) | Video/Voice Quality Mean Opinion Score | Application Response Time | Packet Loss | Latency | Jitter | Throughput |
| Applications and Services - End Nodes (Host/Workstations, Network Appliance, Server (Advanced, Simple)) | | | | | | | | | | | | | | | | | |
| | Web-based transactions | | | | | | | | | | | | | | | | |
| | Client (Internet Explorer) | HTTP (80) | TCP (6) | | | | | | | | | | | | | | |
| | Server (IIS) | HTTP (80) | TCP (6) | | | | | | | | | | | | | | |
| | Client (Internet Explorer) | HTTPS (443) | TCP (6) | | | | | | | | | | | | | | |
| | Server (IIS) | HTTPS (443) | TCP (6) | | | | | | | | | | | | | | |
| | Domain Name System resolution | | | | | | | | | | | | | | | | |
| | Client | DNS query (53) | UDP (17) | | | | | | | | | | | | | | |
| | Server | DNS response (53) | UDP (17) | | | | | | | | | | | | | | |
| | Server | DNS zone transfers (53) | TCP (6) | | | | | | | | | | | | | | |
| | Mail Exchange | | | | | | | | | | | | | | | | |
| | Client (Outlook) | IMAP/RPC | TCP (6) | | | | | | | | | | | | | | |
| | Server (Exchange) | IMAP/RPC | TCP (6) | | | | | | | | | | | | | | |
| | Server (Exchange) | SMTP (25) | TCP (6) | | | | | | | | | | | | | | |
| | Client | POP-3 (110) | TCP (6) | | | | | | | | | | | | | | |
| | Client | SMTP (25) | TCP (6) | | | | | | | | | | | | | | |
| | File Transfer | | | | | | | | | | | | | | | | |
| | Client/IE or FTP client | FTP (20,21) | TCP (6) | | | | | | | | | | | | | | |

| Highlighted cells identify what applies to each sub-category of the objectives. This applies to the system and individual components. | | | | User Metrics | | | | | Performance Metrics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | IPv6 Functionality | | Application | | | Application | | | | Network | | | | |
| Objective | Application or Category Client/Server | Protocol (Dest. Port) | Transport (Protocol #) | Limited Functions (IP Addressing) | Basic Functions (Application support) | Message Completion Threshold>=90%, Objective>=90% | Data Integrity Threshold>=99.9% Objective>=99.9% | Call Completion rate | Application Response Time | Transactions per Second | Voice Quality Mean Opinion Score (MOS) | Video/Voice Quality Mean Opinion Score | Application Response Time | Packet Loss | Latency | Jitter | Throughput |
| | Server/IIS | FTP (20,21) | TCP (6) | | | | | | | | | | | | | | |
| | Client (FTP Secure) | FTPS (TLS/SSL-) | TCP (6) | | | | | | | | | | | | | | |
| | Server/IIS | FTPS (TLS/SSL-) | TCP (6) | | | | | | | | | | | | | | |
| | Client (Secure Copy) | SCP (SSH-22) | TCP (6) | | | | | | | | | | | | | | |
| | VoIP | | | | | | | | | | | | | | | | |
| | Cisco Call Manager | H.323 (multiple) | TCP/UDP | | | | | | | | | | | | | | |
| | End User Device | H.323 (multiple) | TCP/UDP | | | | | | | | | | | | | | |
| | SIP Server | SIP (5060) | TCP/UDP | | | | | | | | | | | | | | |
| | End User Device | SIP (5060) | TCP/UDP | | | | | | | | | | | | | | |
| | VTC | | | | | | | | | | | | | | | | |
| | Video call | H.323 (multiple) | TCP/UDP | | | | | | | | | | | | | | |
| | Management/etc | | | | | | | | | | | | | | | | |
| | Ping/Traceroute | ICMP | ICMP (1) | | | | | | | | | | | | | | |
| | Ping V6 | ICMPv6 | ICMP (58) | | | | | | | | | | | | | | |
| | Secure Shell | SSH (22) | TCP (6) | | | | | | | | | | | | | | |
| | Network Time Client | NTP (123) | UDP (17) | | | | | | | | | | | | | | |
| | Network Time Server | NTP (123) | UDP (17) | | | | | | | | | | | | | | |
| | Network Management Client | SNMP (161) | UDP (17) | | | | | | | | | | | | | | |
| | Network Management Server | SNMP trap (162) | UDP (17) | | | | | | | | | | | | | | |

| Highlighted cells identify what applies to each sub-category of the objectives. This applies to the system and individual components. | | | | User Metrics | | | | | Performance Metrics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | IPv6 Functionality | | Application | | | Application | | | | Network | | | | | |
| Objective | Application or Category Client/Server | Protocol (Dest. Port) | Transport (Protocol #) | Limited Functions (IP Addressing) | Basic Functions (Application support) | Message Completion Threshold>=90%, Objective>=90% | Data Integrity Threshold>=99.9% Objective>=99.9% | Call Completion rate | Application Response Time | Transactions per Second | Voice Quality Mean Opinion Score (MOS) | Video/Voice Quality Mean Opinion Score | Application Response Time | Packet Loss | Latency | Jitter | Throughput |
| | Dynamic Host Configuration Client | DHCP (67,68) | UDP (17) | | | | | | | | | | | | | | | |
| | Dynamic Host Configuration Server | DHCP (67,68) | UDP (17) | | | | | | | | | | | | | | | |
| | Trivial File Transfer Client | TFTP (69) | UDP (17) | | | | | | | | | | | | | | | |
| | Trivial File Transfer Server | TFTP (69) | UDP (17) | | | | | | | | | | | | | | | |
| Transport and Routing - Intermediate Node (Router, L3 Switch) | | | | | | | | | | | | | | | | | | |
| | Transport | | | | | | | | | | | | | | | | | |
| | Ping/Traceroute | ICMP | ICMP (1) | | | | | | | | | | | | | | | |
| | IPv4 Multicast Group Management | IGMP | IGMP (2) | | | | | | | | | | | | | | | |
| | Ping V6 | ICMPv6 | ICMP (58) | | | | | | | | | | | | | | | |
| | | ND (Node Discovery) | ICMP (58) | | | | | | | | | | | | | | | |
| | | MRD (Multicast Router Discovery) | ICMP (58) | | | | | | | | | | | | | | | |
| | | Authentication Header (AH) | AH (51) | | | | | | | | | | | | | | | |
| | | Encap Security Payload (ESP) | ESP (50) | | | | | | | | | | | | | | | |
| | Routing | | | | | | | | | | | | | | | | | |

| Highlighted cells identify what applies to each sub-category of the objectives. This applies to the system and individual components. | | | | User Metrics | | | | | Performance Metrics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | IPv6 Functionality | | Application | | | Application | | | | Network | | | | |
| Objective | Application or Category Client/Server | Protocol (Dest. Port) | Transport (Protocol #) | Limited Functions (IP Addressing) | Basic Functions (Application support) | Message Completion Threshold>=90%, Objective>=90% | Data Integrity Threshold>=99.9% Objective>=99.9% | Call Completion rate | Application Response Time | Transactions per Second | Voice Quality Mean Opinion Score (MOS) | Video/Voice Quality Mean Opinion Score | Application Response Time | Packet Loss | Latency | Jitter | Throughput |
| | | EIGRP (224.0.0.10) | EIGRP (88) | | | | | | | | | | | | | | |
| | | OSPF (224.0.0.5,6) | OSPF (89) | | | | | | | | | | | | | | |
| | | BGP (179) | TCP (6) | | | | | | | | | | | | | | |

Table 6. Functionality Test Matrix

### 2. Phase 2: Conformance

Phase 2 testing will be stand-alone conformance testing of the individual system components. The system is comprised of both end nodes and network devices. These components are categorized in different Product Classes and have unique conformance test requirements. These test requirements can be found in the DDS-M Test Procedures at MCTSSA (MCTSSA IPv6 Test Procedures) and are an excerpt from Section 3 of the DoD IPv6 Standard Profiles for IPv6 Capable Products Version 6.0. The Spirent Test Center and Ixia Conformance applications will be used to evaluate the component against the applicable RFCs and standards.

Each individual module of the DDS-M will be tested by itself against the Conformance applications of the test tools being used. The configurations of the Suites will remain the same from Phase 1 (Suite1=Legacy and Suite2=Enhanced).

### 3. Phase 3: Security

Phase 3 testing will be security testing of the security or IA devices within the system. This phase will be scheduled at a later time, as the requirements are still evolving.

### 4. Phase 4: Interoperability

Phase 4 testing will be interoperability testing of the system. This will include both internal (MAGTF) and external (Joint) interoperability. Interoperability testing can be scheduled as part of Phase 1 or as a separate phase to support unique JITC testing requirements. JITC normally tests voice, video and data exchanges between USMC and Joint systems. For the purpose of this thesis, Interoperability will be tested alongside Phase 1. JITC has test scripts that emulate OSI Layers 2–4 on Joint Systems and those will be used for the Interoperability Phase.

## C. EVALUATION CRITERIA

The evaluation criteria for each test case or requirement is provided in the Internet Protocol version 6 Test Procedures (MCTSSA IPv6 Test Procedures). Each requirement will be evaluated with either Pass (P) or Fail (F). “Pass” indicates the requirement was met. “Fail” indicates the requirement was not met. The user metrics and interoperability test results will be evaluated against DoD specifications identified in Tables 7 and 8, provided by JITC.

| IE # | Name | Producer/ Sender ID | Consumer/ Recipient ID | Critical | Interface Ref (See Table 4–4) | Criteria | |
|---|---|---|---|---|---|---|---|
| | | | | | | Threshold | Objective |
| 1 | Unclassified Data | Server 1 | Workstation 1 | Yes | I1 | ≥ 90% Transmitted, ≥ 99.9% Data Integrity | ≥ 90% Transmitted, ≥ 99.9% Data Integrity |

**LEGEND:**
I Interface
ID Identification
IE Information Exchange
Ref Reference

Table 7. Information Exchange Requirements

| I # | Interface | Version | Critical | KIP | Criteria | |
|---|---|---|---|---|---|---|
| | | | | | Threshold | Objective |
| I1 | Switch/Router Port | | Yes | N/A | ≥ 90% Transmitted, ≥ 99.9% Data Integrity | ≥ 90% Transmitted, ≥ 99.9% Data Integrity |

**LEGEND:**
I Interface
KIP Key Interface Profile

Table 8. Information Exchange Thresholds Requirements

## D. PROBLEM REPORTING

All incidents, anomalies, problems, or failures observed during the test will be reported via a Trouble Incidence Report (TIR) and recorded in a daily test log. Information from the Daily Test Logs will be combined into a Master Test Log upon completion of the event. The notes from the test logs, TIRs and collected data will be used for problem analysis. The result of the analysis will be reported in the final test report. All generated TIRs will be archived in the MCTSSA Configuration Management library.

## E. SUSPENSION CRITERIA AND RESUMPTION REQUIREMENTS

No suspension criteria or resumption requirements have been established. Individual test cases may require suspension, resumption, or possibly termination. The decision to suspend or resume testing will be made by the Test Director and Team Lead.

## F. TEST SCHEDULE

Table 9, Plan of Action and Milestones (POA&M), identifies a template for the test schedule from planning through reporting. The start and finish dates should be actual dates and the duration period should represent calendar days. The due date listed will be the original due date listed from the Test Plan or adjusted due date based on the approved deviation extending the test.

| POA&M | | | | | | |
|---|---|---|---|---|---|---|
| **Task Name** | **Start** | **Finish** | **Duration** | **Due Date** | **Status** | **Comments** |
| **IPv6 Test** | | | | | | |
| Team kick-off | | | | | | |
| Develop Test Plan | | | | | | |
| Test Readiness Review | | | | | | |
| Prepare Test Lab | | | | | | |
| Execute Test | | | | | | |
| Data Analysis | | | | | | |
| Develop Draft Test Report | | | | | | |
| QA Review | | | | | | |
| TCG review / Adjudication | | | | | | |
| Review and Route | | | | | | |
| Test Report Signed | | | | | | |

Table 9. POA&M

# IV. CONCLUSION AND RECOMMENDATIONS

## A. FUTURE WORK AT MCTSSA

### 1. The Foundation has been Laid

Once the DDS-M completes testing, all other tactical programs of record will be tested behind (while attached to) the DDS-M. Preliminary tests indicate that the DDS-M will have no issues with passing the Dual Stacked portions of the requirements in the USMC IPv6 Transition Plan, so a lab has been built that will emulate the DDS-M at MCTSSA.

The test plan laid out goes into great detail for functionality and performance testing Layers 2–4 of the OSI Model on the DDS-M. Further research needs to be conducted into the area of IPv6 Security; the focus of this thesis is on performance, conformance, and interoperability, but Security should not be neglected in follow on work(s).

### 2. The Need for an IPv6 Lead

A need exists at MCTSSA to lead this efforts. Headquarters Marine Corps is pushing this effort, but the Programs of Record rely on MCTSSA to perform the appropriate testing for this transition. The ideal individual to occupy this billet will meet the below requirements:

- Marine Corps Captain
- Information Technology Management and/or a Computer Science Masters Degree
- Communications Officer (0602) Military Occupation Specialty
- Deployed and/or Combat Experience

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